EXPLOITING AEROBIC FITNESS TO REDUCE RISK OF HYPOBARIC DECOMPRESSION SICKNESS

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ABSTRACT

INTRODUCTION: Decompression sickness (DCS) is multivariable. But we hypothesize an aerobically "fit" person is less likely to experience hypobaric DCS than an "unfit" person given that fitness is exploited as part of the denitrogenation (prebreathe, PB) process prior to an altitude exposure. Aerobic fitness is peak oxygen uptake (VO2pk, ml/kg/min). METHODS: Treadmill or cycle protocols were used over 15 years to determine VO2pks. We evaluated dichotomous DCS outcome and venous gas emboli (VGE) outcome detected in the pulmonary artery with Doppler ultrasound associated with VO2pk for two classes of experiments: 1) those with no PB or PB under resting conditions prior to ascent in an altitude chamber, and 2) PB that included exercise for some part of the PB. There were 165 exposures (mean VO2pk 40.5 ± 7.6 SD) with 25 cases of DCS in the first protocol class and 172 exposures (mean VO2pk 41.4 ± 7.2 SD) with 25 cases of DCS in the second. Similar incidence of the DCS (15.2% vs. 14.5%) and VGE (45.5% vs. 44.8%) between the two classes indicates that decompression stress was similar. The strength of association between outcome and VO2pk was evaluated using univariate logistic regression. RESULTS: An inverse relationship between the DCS outcome and VO2pk was evident, but the relationship was strongest when exercise was done as part of the PB (exercise PB, coef. = -0.058, p = 0.07; rest or no PB, coef. = -0.005, p = 0.86). There was no relationship between VGE outcome and VO2pk (exercise PB, coef. = -0.003, p = 0.89; rest or no PB, coef. = 0.014, p = 0.50). CONCLUSIONS: A significant change in probability of DCS was associated with fitness only when exercise was included in the denitrogenation process. We believe a fit person that exercises during PB efficiently eliminates dissolved nitrogen from tissues.

INTRODUCTION

The expression of signs and symptoms of decompression sickness (DCS) are dictated by many factors, both subject-specific and environmental.

Aerobic fitness, as VO2 peak (ml O2 / kg / min), may be linked with resistance to DCS and venous gas emboli (VGE) (1 - 6).

It is not possible to distinguish a "fit" person from an "unfit" person based on resting oxygen (O2) consumption, both consume about 3.5 ml / kg / min.

So why should aerobic fitness be of any value during denitrogenation (prebreathe, PB) prior to ascent in an altitude chamber if fit and unfit subjects rest during the PB?

Hypothesis: Exercise during the PB is a necessary condition to understand if aerobic fitness is associated with hypobaric DCS and VGE outcomes.

METHODS

Two general classes of experiments that include VO2pk information are available from the NASA Hypobaric Decompression Sickness Database:

165 exposures with 25 cases of DCS where no PB or PB under resting conditions was performed prior to ascent in an altitude chamber, and

172 exposures with 25 cases of DCS where exercise was performed during the PB prior to ascent to altitude.

Table I shows summary information from the two classes of experiments done to understand more about hypobaric DCS.

TABLE I: Summary of Information from Two Classes of Experiments about Hypobaric DCS

	total n	male n	female n	mean VO2pk (ml O2/kg/min)	mean age (years)	mean altitude	mean exposure time (min)	ambulation at altitude
Exercise PB	172	130	42	41.4	32.9	4.3 psia	240	no one ambulated
Resting PB	165	121	44	40.5	32.6	6.5 psia	180	75% of sample

	%DCS	%VGE*	mean DCS onset (min)	mean VGE onset (min)
Exercise PB	14.5	44.8	122	90
Resting PB	15.2	45.5	101	62

* VGE are bubbles in the venous blood detected in the pulmonary artery from the precordial position using Doppler ultrasound bubble detectors.

The similarity of the DCS (15.2% versus 14.5%) and VGE (45.5% versus 44.8%) incidence between the two classes of experiments indicates that the decompression stress was similar in both cases.

The strength of association between DCS and VGE outcome and VO2pk was evaluated using univariate logistic regression, with maximum likelihood optimization.

RESULTS

The VO2pk for subjects who perform no PB or resting PB has no bearing on the DCS outcomes as seen in Fig. 1, the slope is essentially zero.

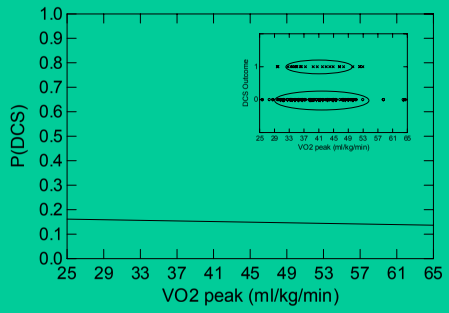

Figure 1: Linear regression using 165 exposures where 25 of 165 exposures resulted in DCS (15.1%) after protocols that had no PB period or included rest during the PB where most subjects (75%) ambulated at altitude. Logistic regression coefficient for VO2pk was - 0.005 with p-value of 0.866. Inset shows no particular "visual" association between VO2pk and the DCS outcome.

However, if you exercise by a percentage of your VO2pk during PB as a means to accelerate denitrogenation, it appears that that if all else is equal, you are at less risk for DCS if you are fit than if you are unfit, as seen in Fig. 2.

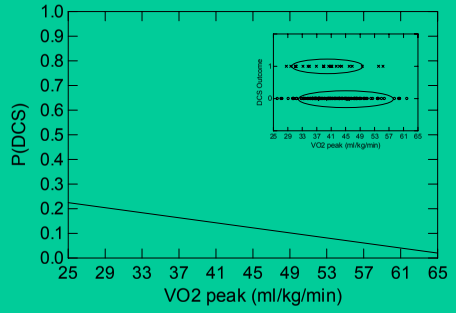

Figure 2: Linear regression using 172 exposures (165 from PRP and 7 from NASA) where 25 of 172 exposures resulted in DCS (14.5%) after PB protocols that included exercise during the PB where all subjects did not ambulate at altitude. Logistic regression coefficient for VO2pk was - 0.058 with p-value of 0.07. Inset shows a "visual" inverse association between VO2pk and the DCS outcome.

An identical analysis performed on the dichotomous VGE outcome showed there was no association between VO2pk and incidence of VGE regardless if exercise was done during the PB.

CONCLUSIONS / DISCUSSION

P(VGE) outcome is not associated with fitness regardless if exercise is done during the PB (exercise PB, coef. = -0.003, p = 0.89; rest or no PB, coef. = 0.014, p = 0.50).

P(DCS) outcome is not associated with fitness unless fitness is exploited as part of the denitrogenation process (exercise PB, coef. = -0.058, p = 0.07; rest or no PB, coef. = -0.005, p = 0.86).

Exercise is a necessary condition for a fit and unfit person to reduce their risk of DCS.

However, for the unfit person a greater percentage of VO2pk must be prescribed in the same PB interval, or more PB time is needed at the lower percentage of VO2pk, or some other combination if both fit and unfit persons are to have comparable DCS risk.

Example: Based on a statistical model that relates exercise to a change in half-time compartment for nitrogen washout (2), a fit (50 ml / kg / min) and unfit (30 ml / kg / min) non-ambulatory person does an exercise PB at 60% of VO2pk while breathing 100% O2 from a mask and then ascends to 4.3 psia (30,250 feet) for a 4-hr exposure.

PB Time Interval	VO2 consumption rate (ml / kg / min) Fit Subject	Unfit Subject
0 - 15	30	18 (exercise interval)
15 - 30	4	4 (rest interval)
30 - 45	30	18
45 - 60	4	4
60 - 75	30	18
75 - 90	4	4
90 - 105	30	18
105 - 120	4	4
P(DCS)*	2.3%	15.7% ⟶ ↓
120 - 160	----	4 ↓
P(DCS)	-----	2.3% ⟵

* P(DCS) is computed probability of DCS as percentage.

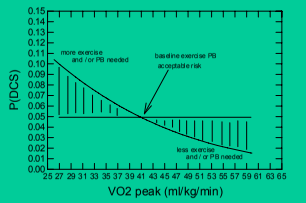

Figure 3. Exploitation of exercise PB results from (2). Once "acceptable risk" is defined for a particular activity, then an exercise PB prescription is created based on your VO2 peak.

It takes 40 additional minutes of resting PB in the unfit subject for both subjects to have a similar computed DCS risk of 2.3%.

We believe that a fit person is better able to eliminate dissolved nitrogen from tissues associated with "pain-only" DCS during PB when exercise as a percentage of VO2pk is included.

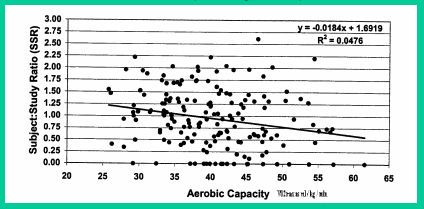

Figure 4. Data from (6) shows modest inverse relationship between altitude DCS susceptibility and VO2max from 43 women and 130 men. Results apply to a combination of no PB, PB under resting conditions, or PB under exercise conditions, which may account for some of the variability. The SSR on the y-axis is a measure of DCS susceptibility, the greater the value the more susceptible the subject (see 6 for details).

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